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(54) Abstract Title
Tuneable dielectric resonator antenna

(57) There is disclosed a dielectric resonator antenna including a dielectric resonator (1) and a grounded substrate (2), the dielectric resonator (1) having a first surface proximal to the grounded substrate (2) and a second surface (3) distal from the grounded substrate (2), a directional feed mechanism (4, 6) associated with the first surface (9) for transferring energy to and from the dielectric resonator (1), and at least one directional conductive element (5) located on the first and/or second surface (3), the dielectric resonator antenna being configured so as to allow a relative directional disposition, by rotation or translation, of the feed mechanism (4, 6) and the at least one conductive element (5) to be varied and thereby to vary a resonant frequency (F_0) of the antenna. An air gap may be provided between the resonator and substrate to increase the antenna bandwidth and resonant frequency.

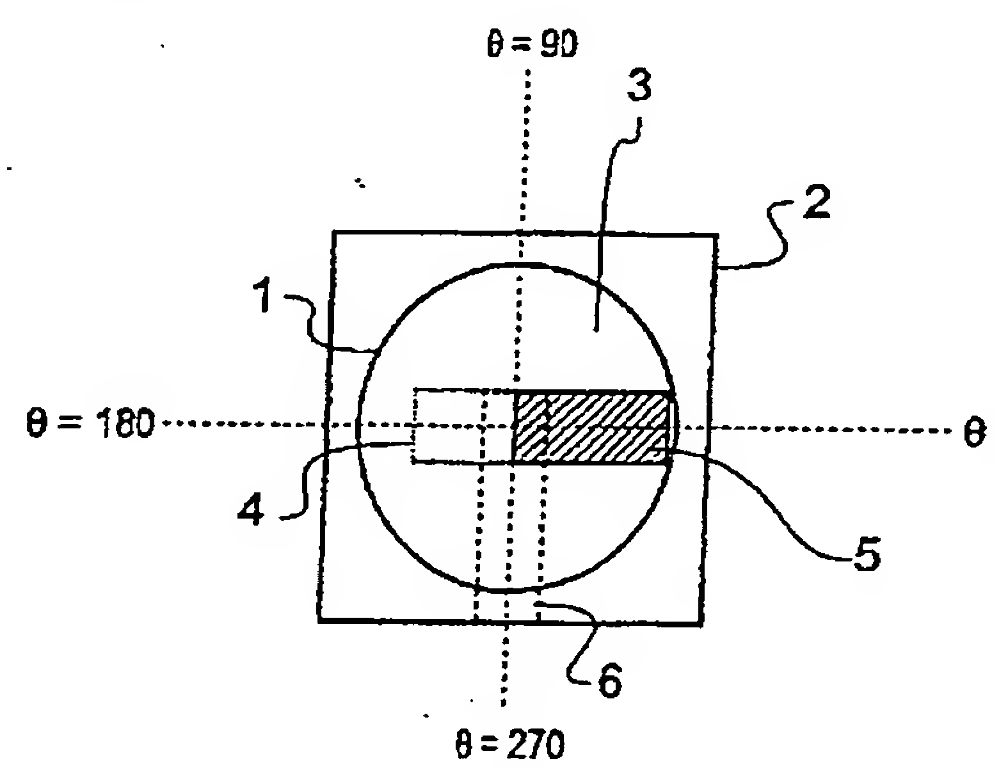

Fig. 1

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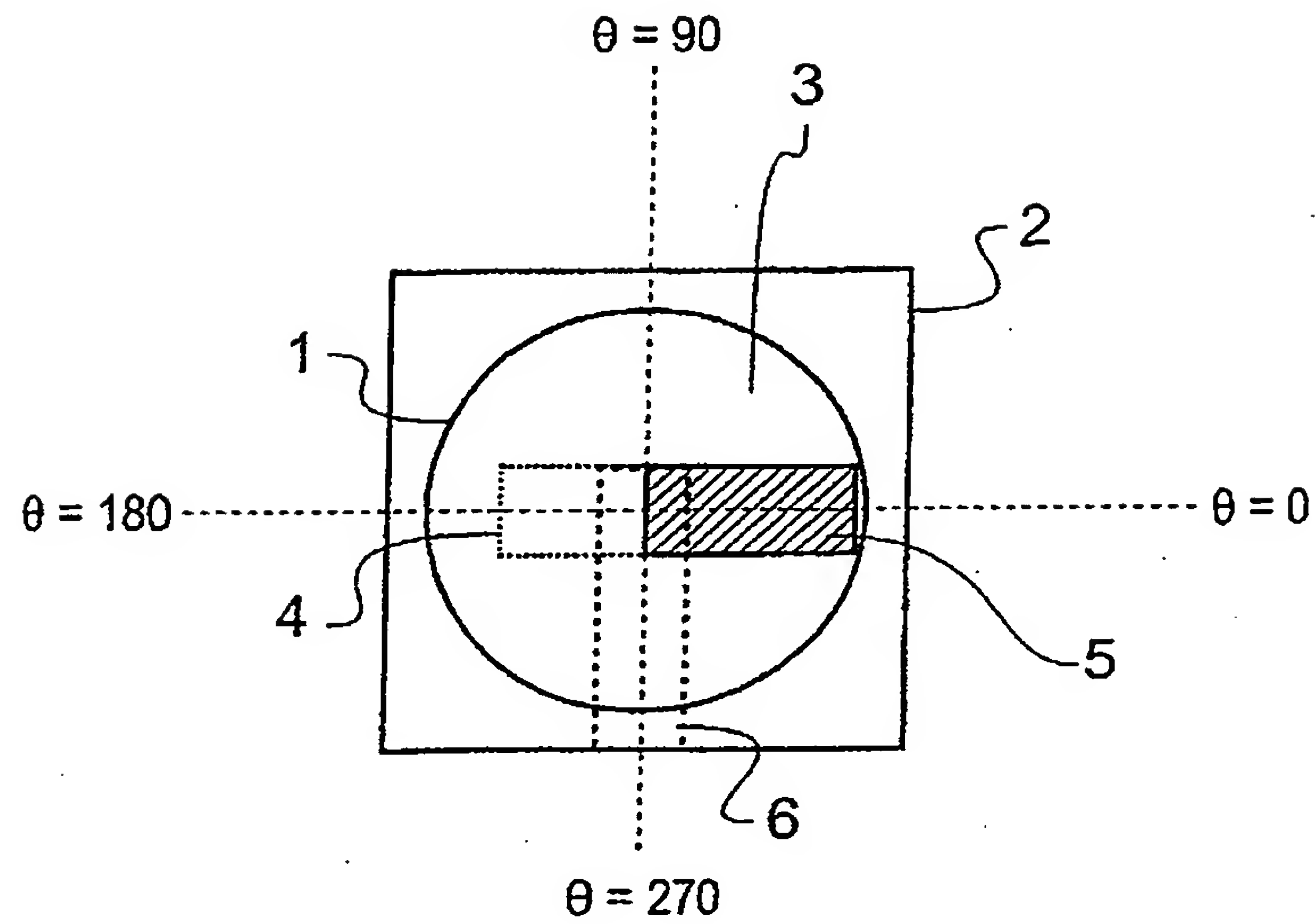

Fig. 1

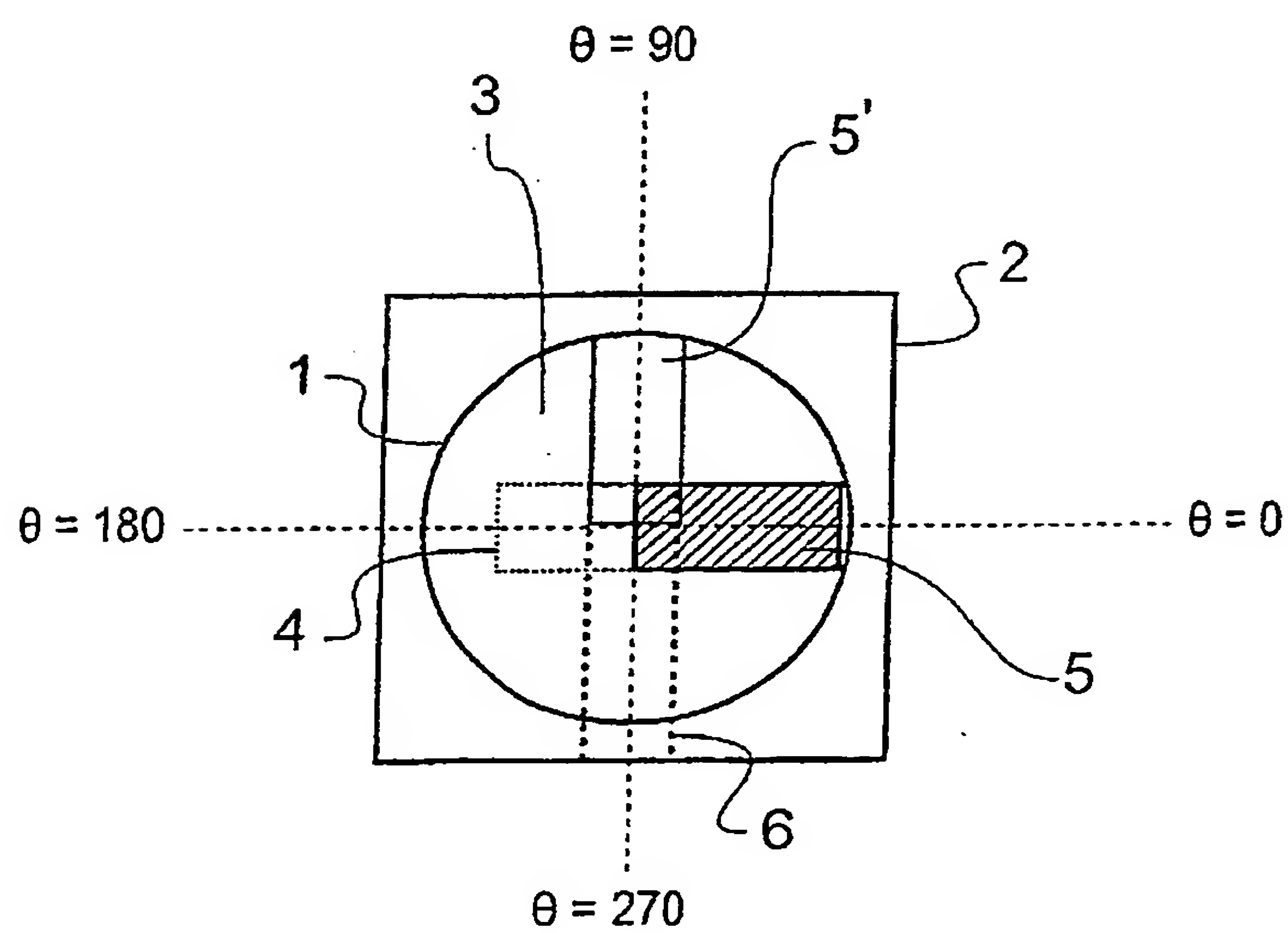

Fig. 2

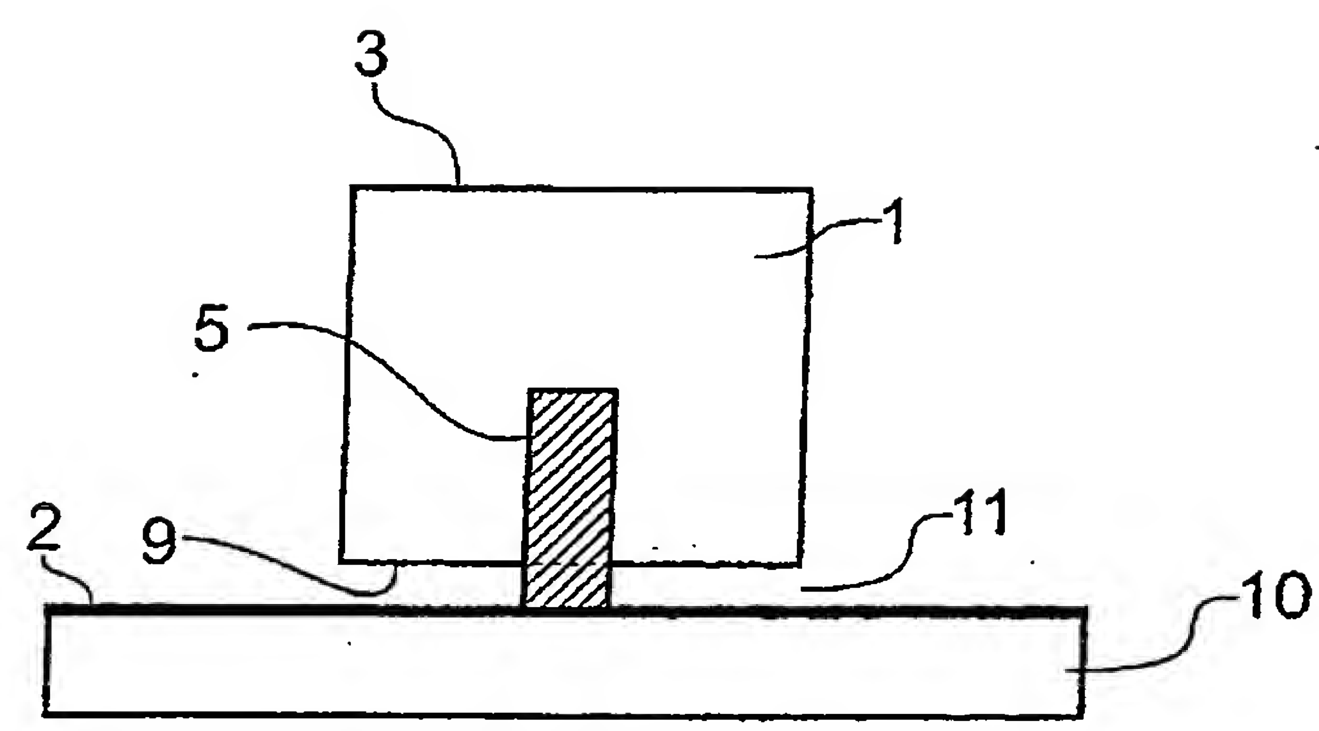

Fig. 3

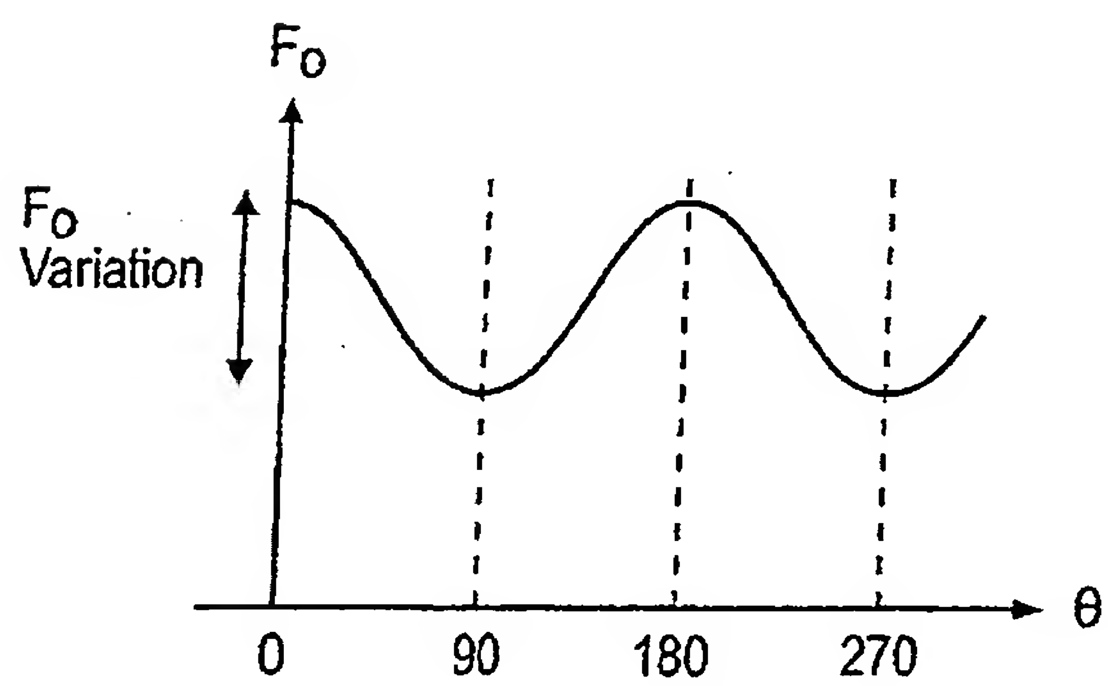

Fig. 4

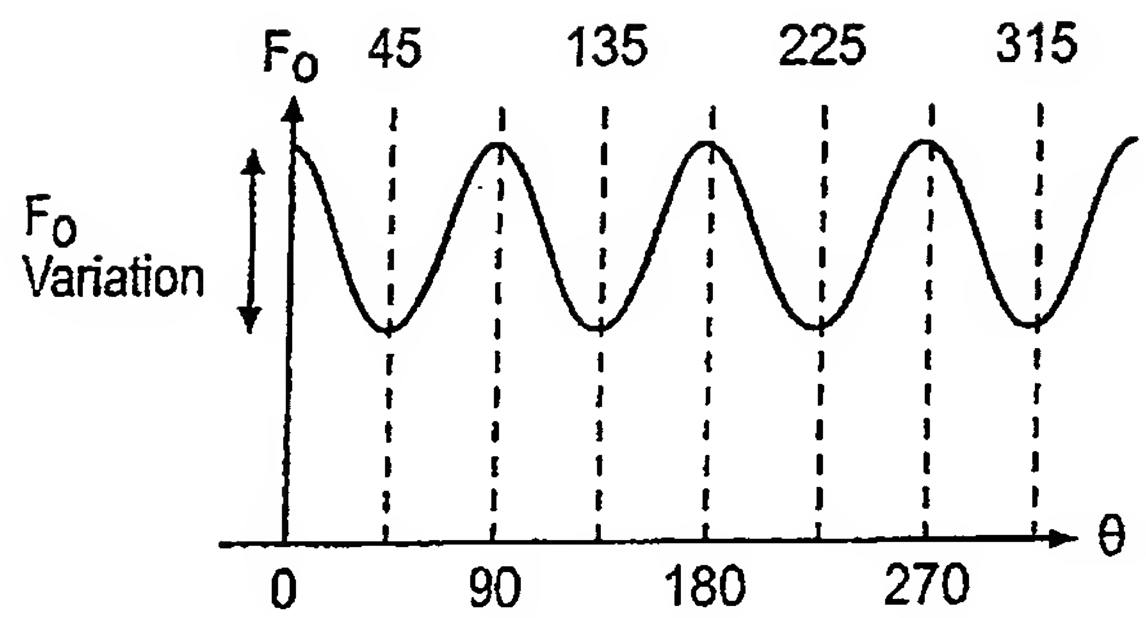
F_0
45
135
225
315
F_0 Variation
θ
0
90
180
270

Fig. 5

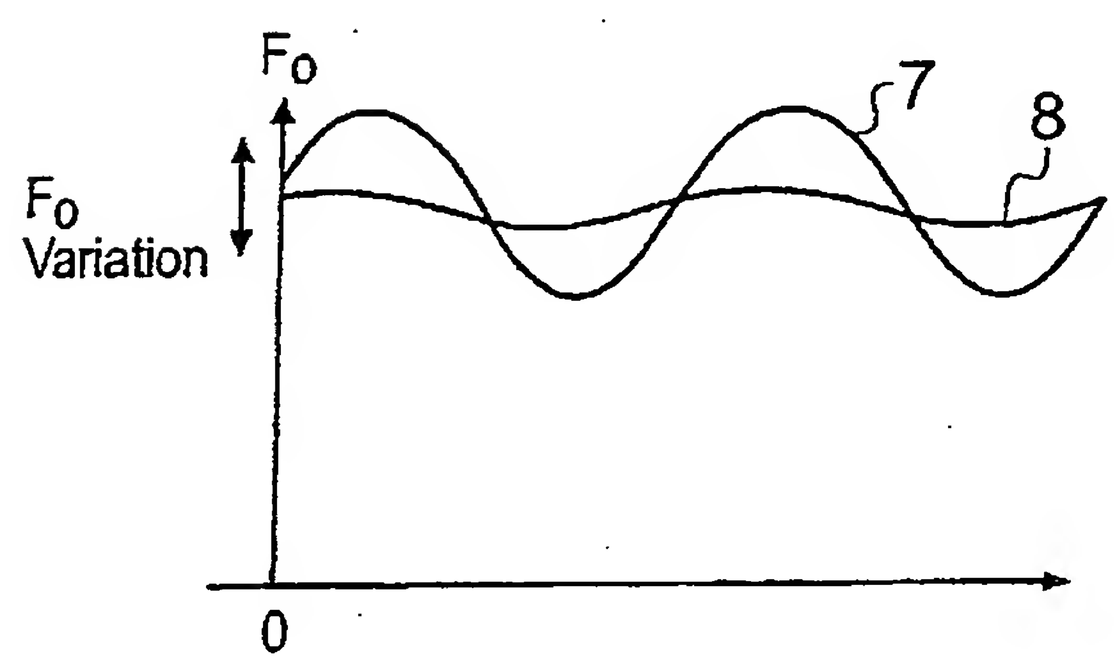
F_0
7
8
F_0 Variation
0

Fig. 6

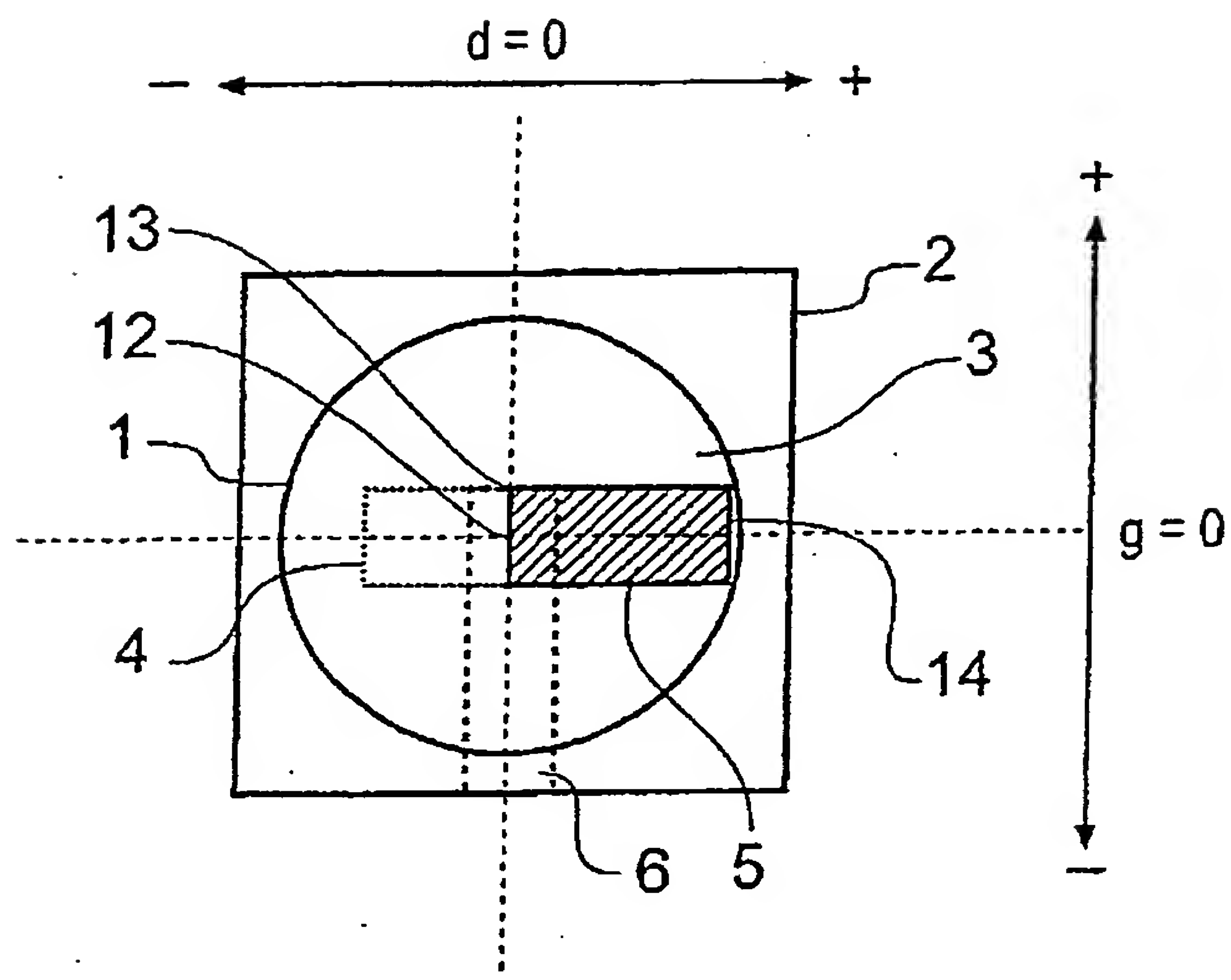
d = 0
−
+
+
−
g = 0
13
12
1
4
2
3
14
6
5

Fig. 7

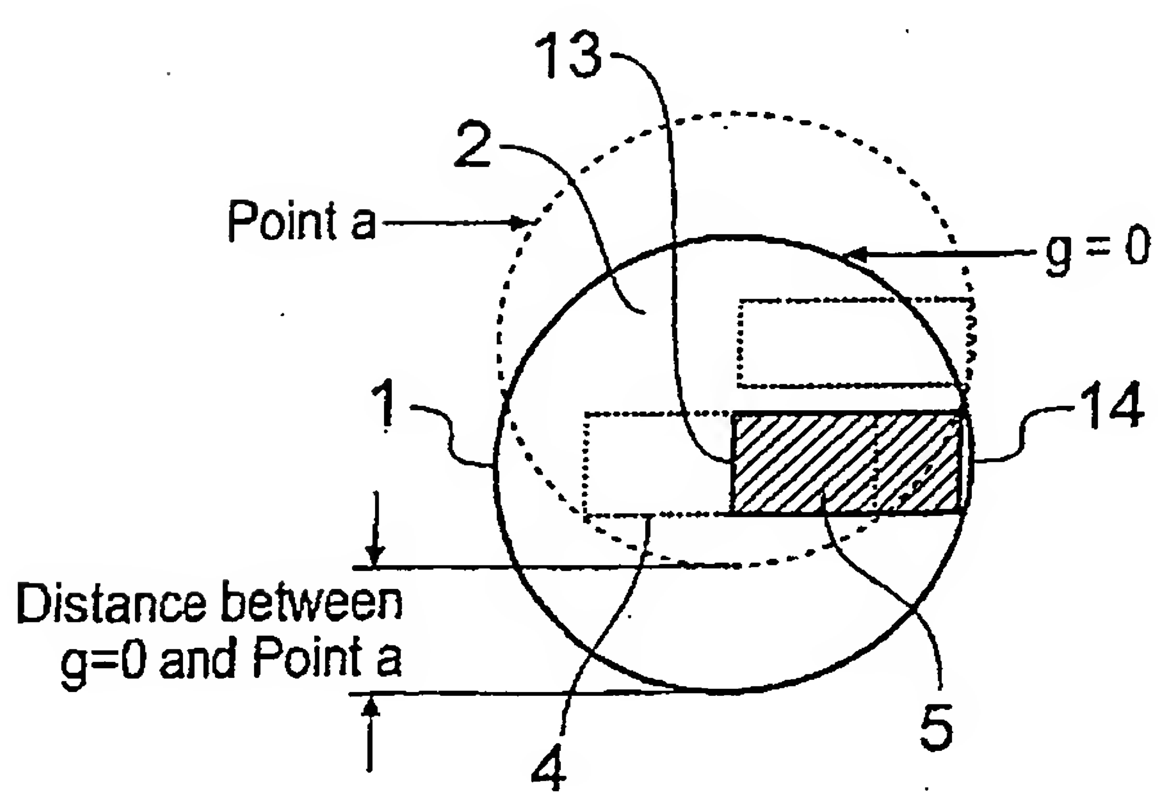
13
2
Point a
g = 0
1
14
Distance between
g=0 and Point a
4
5

Fig. 8

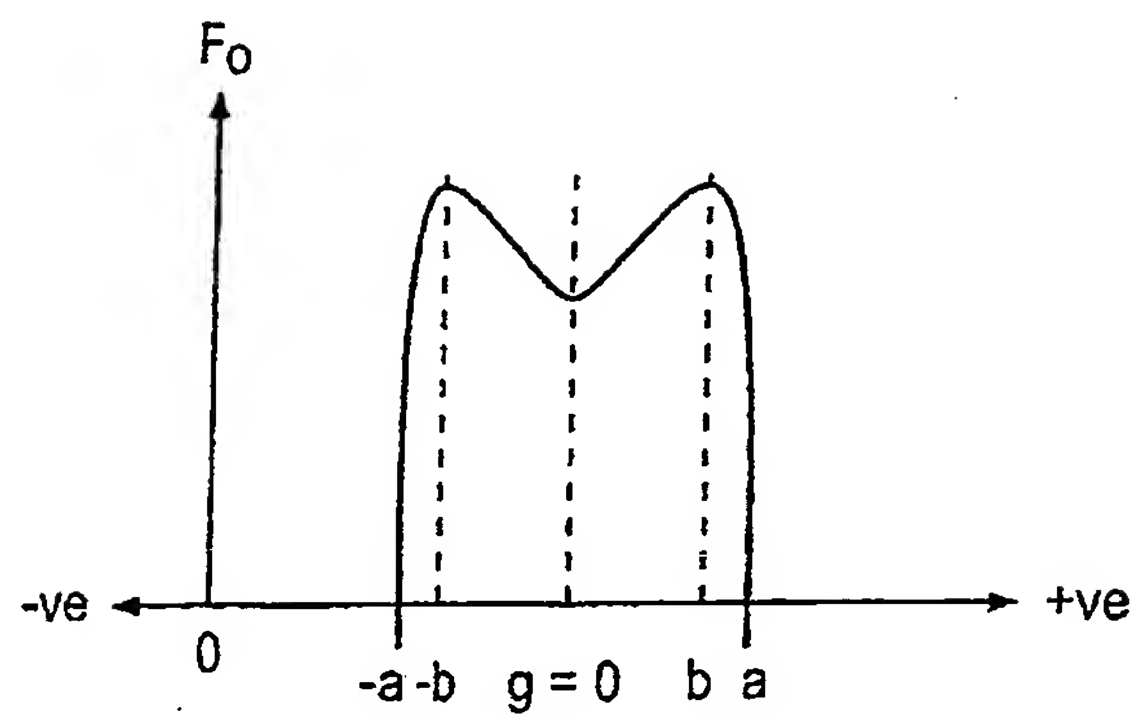

Fig. 9

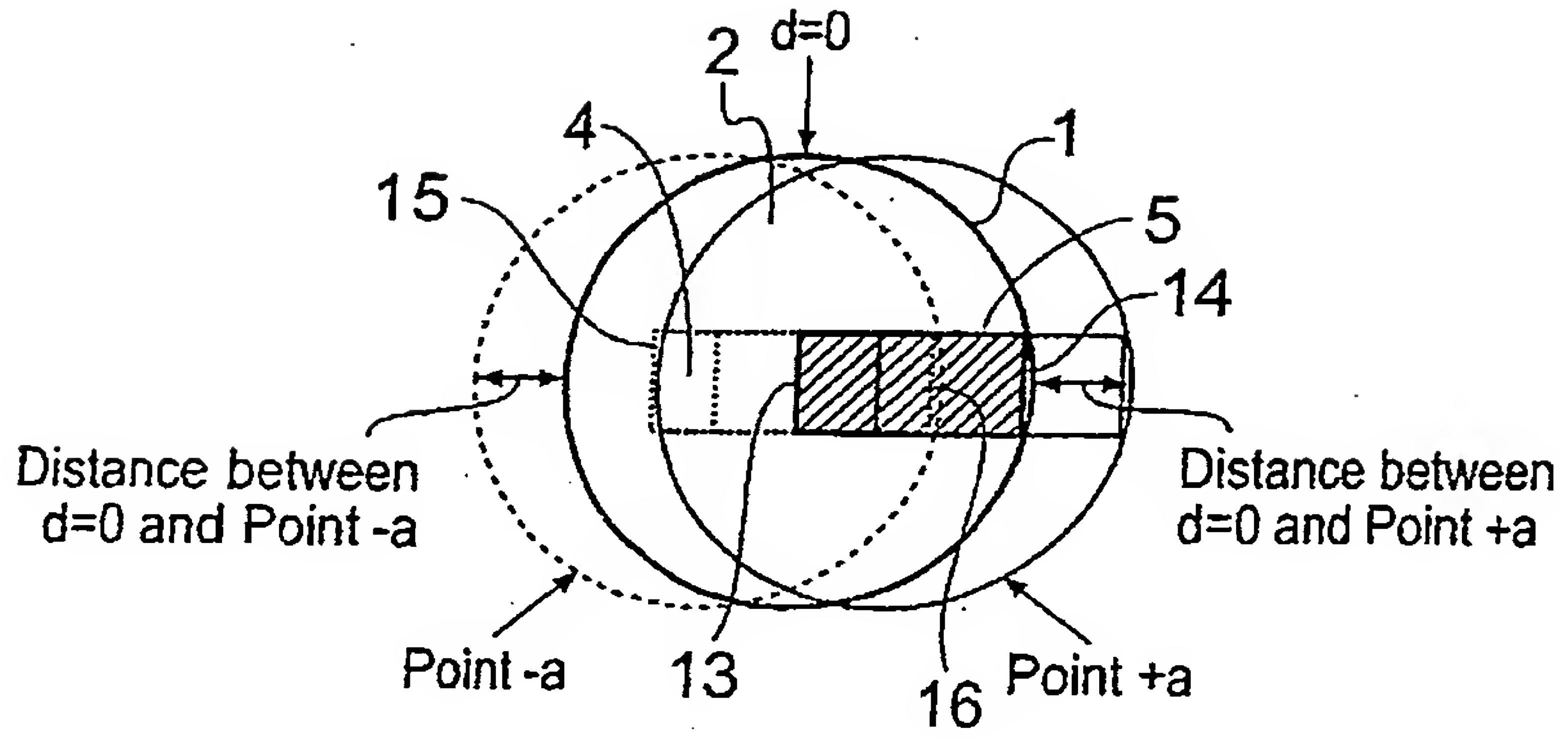
d=0
2
4
1
15
5
14
Distance between
d=0 and Point -a
Distance between
d=0 and Point +a
Point -a
13
16
Point +a

Fig. 10

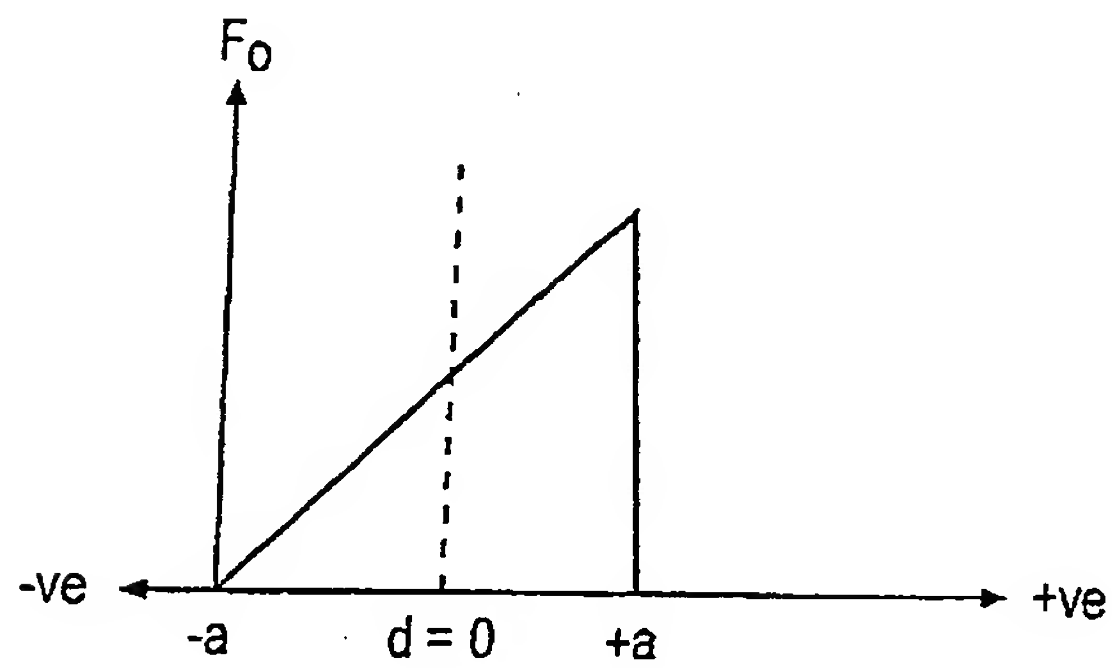
F_0
-ve
+ve
-a
d = 0
+a

Fig. 11

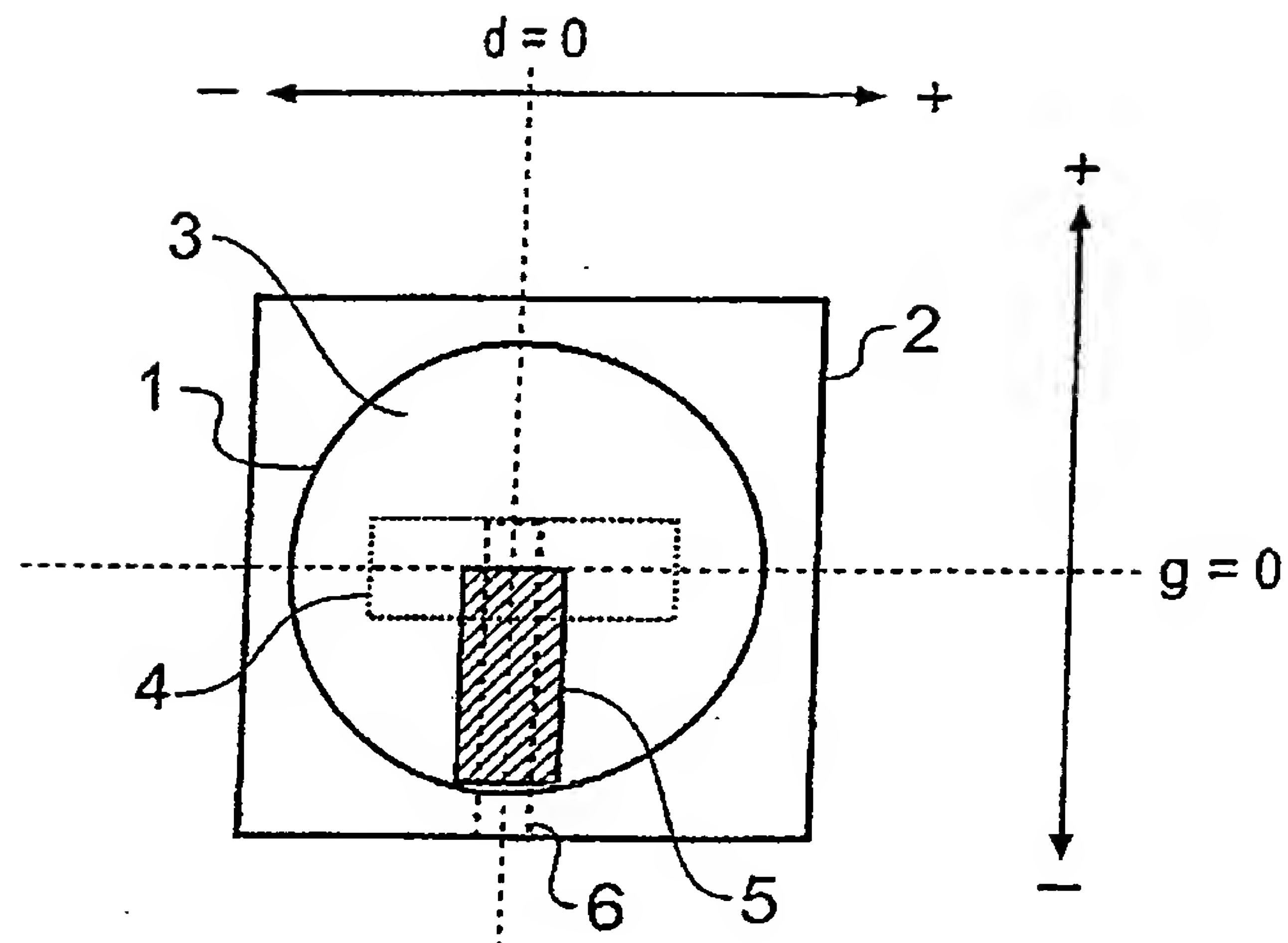
d = 0
−
+
+
3
2
1
g = 0
4
6
5
−

Fig. 12

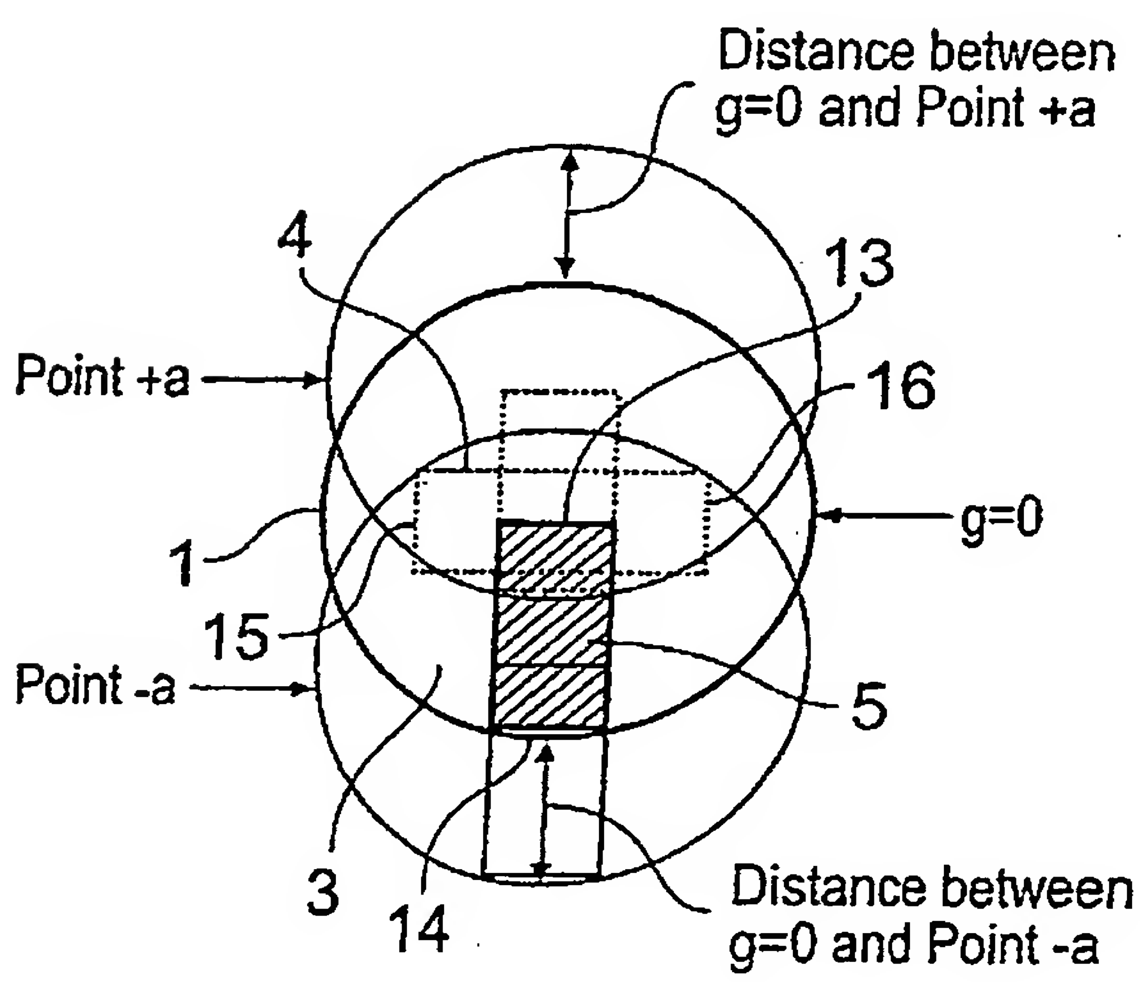
Distance between
g=0 and Point +a
4
13
Point +a
16
g=0
1
15
Point -a
5
3
14
Distance between
g=0 and Point -a

Fig. 13

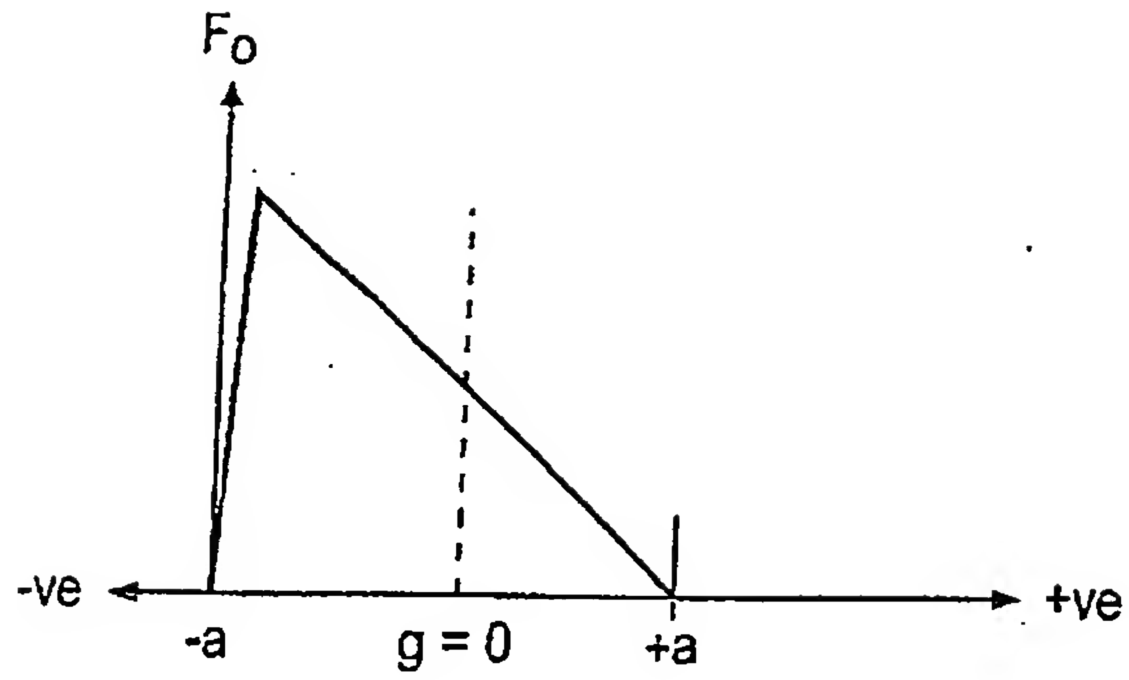
Fo
-ve
+ve
-a
g = 0
+a

Fig. 14

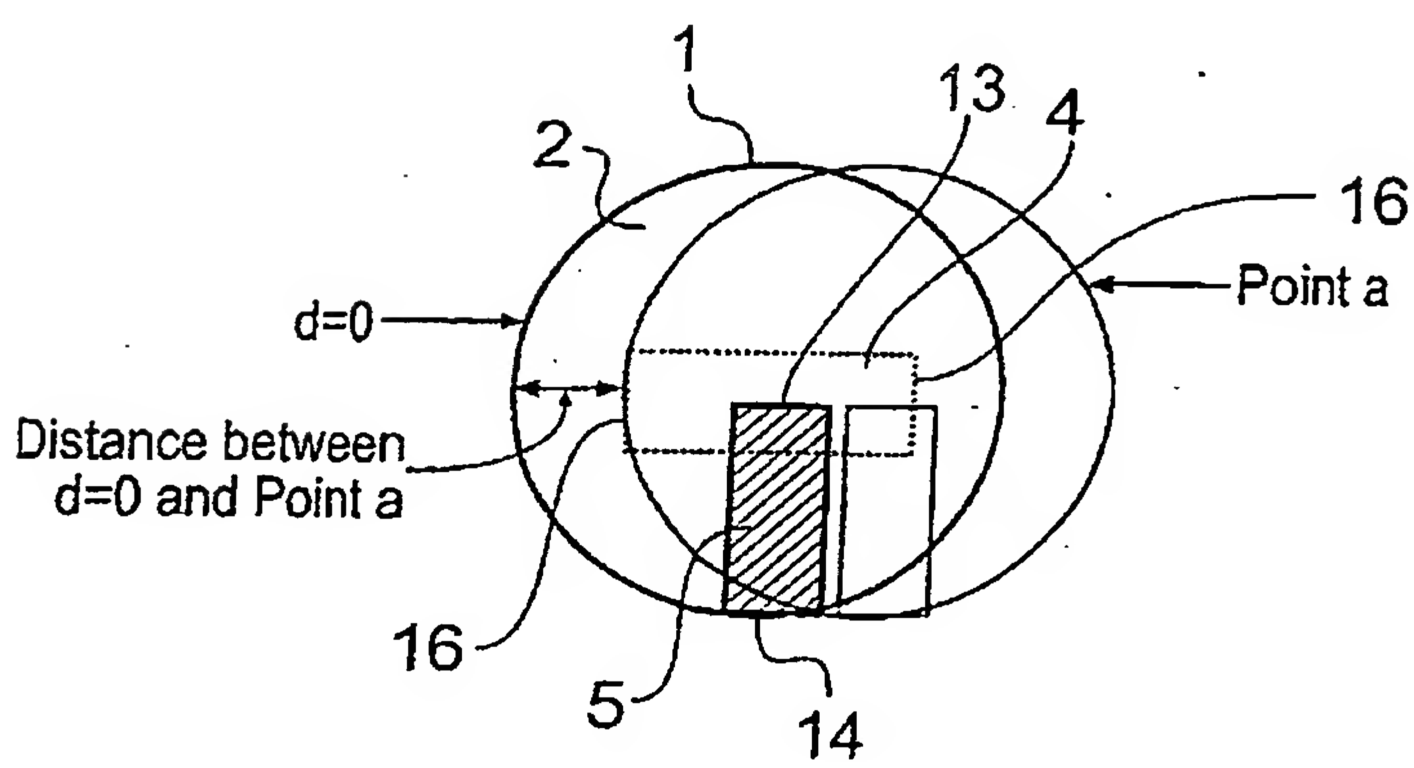
1
2
13
4
16
d=0
Point a
Distance between
d=0 and Point a
16
5
14

Fig. 15

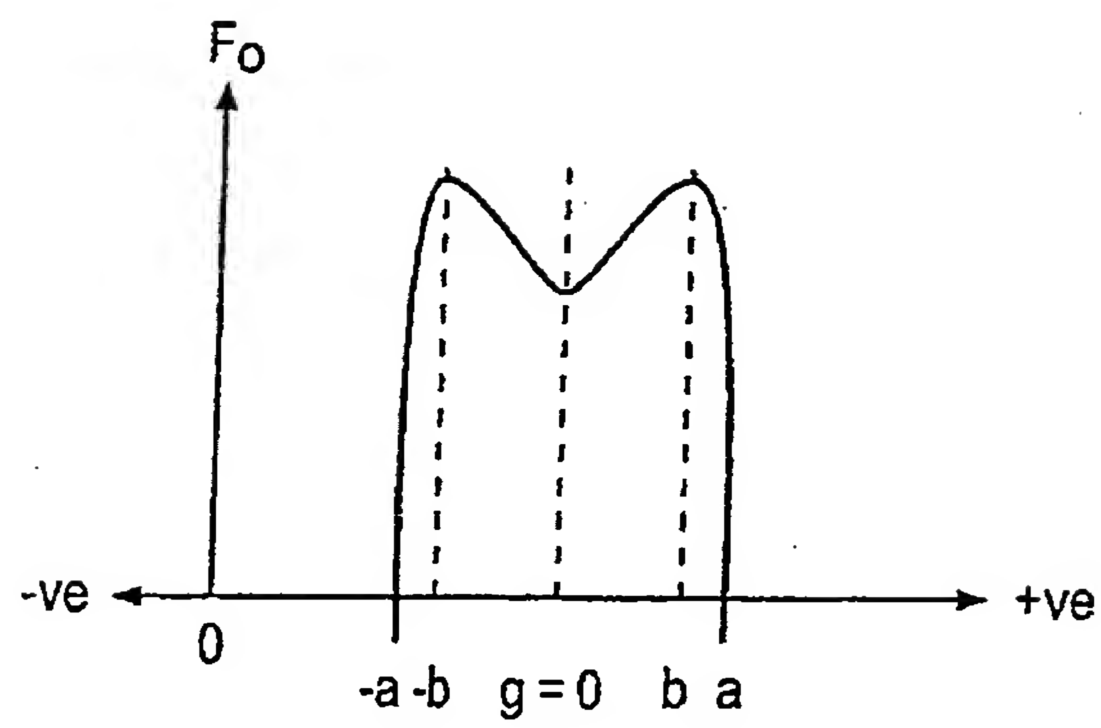

Fig. 16

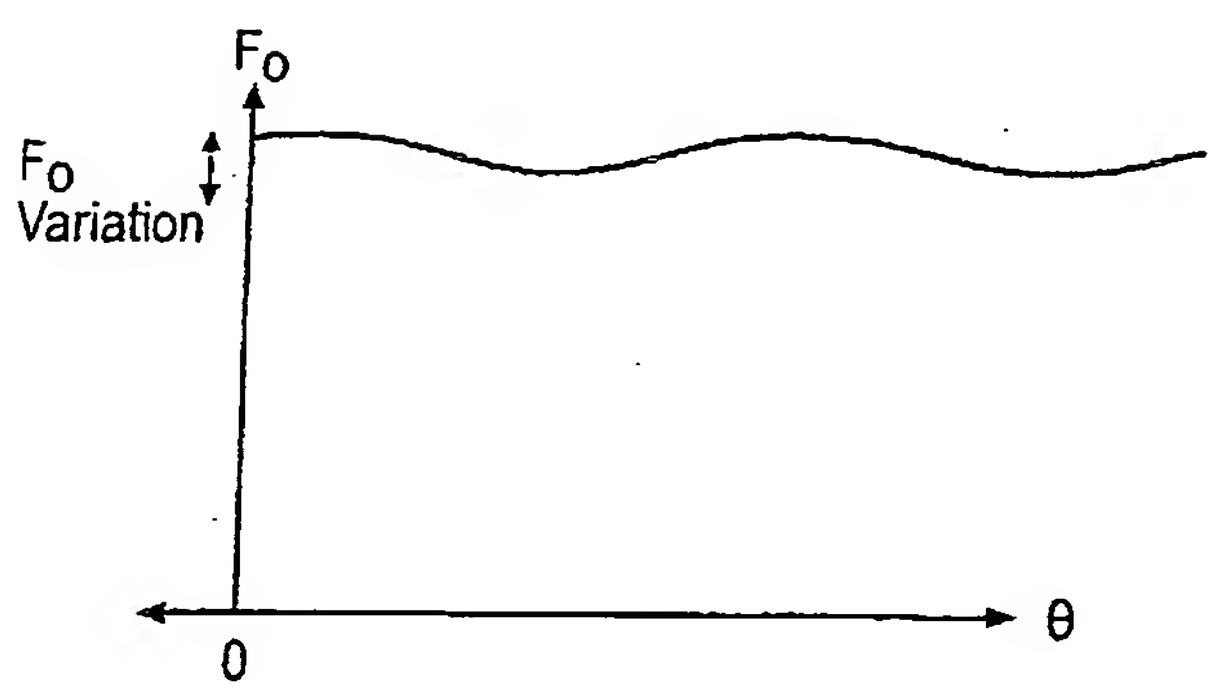

Fig. 17

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TUNEABLE DIELECTRIC RESONATOR ANTENNA

Preamble

The present invention relates to a dielectric resonator antenna (DRA) that changes its resonant frequency in a sinusoidal manner when rotated about a given axis.

Introduction to DRAs

Since the first systematic study of dielectric resonator antennas (DRAs) in 1983 [LONG, S.A., McALLISTER, M.W., and SHEN, L.C.: "The Resonant Cylindrical Dielectric Cavity Antenna", IEEE Transactions on Antennas and Propagation, AP-31, 1983, pp 406-412], interest has grown in their radiation patterns because of their high radiation efficiency, good match to most commonly used transmission lines and small physical size [MONGIA, R.K. and BHARTIA, P.: "Dielectric Resonator Antennas - A Review and General Design Relations for Resonant Frequency and Bandwidth", International Journal of Microwave and Millimetre-Wave Computer-Aided Engineering, 1994, 4, (3), pp 230-247].

The majority of configurations reported to date have used a slab of dielectric material (a dielectric resonator) mounted on a conductive ground plane (a grounded substrate) excited by either a single aperture feed in the ground plane [ITTIPIBOON, A., MONGIA, R.K., ANTAR, Y.M.M., BHARTIA, P. and CUHACI, M: "Aperture Fed Rectangular and Triangular Dielectric Resonators for use as Magnetic Dipole Antennas", Electronics Letters, 1993, 29, (23), pp 2001-2002] or by a single probe inserted into the dielectric material [McALLISTER, M.W., LONG, S.A. and CONWAY G.L.: "Rectangular Dielectric Resonator Antenna", Electronics Letters, 1983, 19, (6), pp 218-219]. Direct excitation by a transmission line has also been reported by some authors [KRANENBURG, R.A. and LONG, S.A.: "Microstrip Transmission Line Excitation of Dielectric Resonator Antennas", Electronics Letters, 1994, 24, (18), pp 1156-1157].

Tuning can have important commercial consequences for DRAs. For example, very narrow band antennas can be configured to act also as front end RF filters and may theoretically be placed exactly on a required frequency by some tuning or auto-tuning process. Alternatively, an antenna design might be configured for the European 1.8GHz GSM band, but could theoretically be simply re-configured for the North American 1.9GHz GSM band by a tuning change, without any further design or production changes.

Tuning DRAs

A number of scientific papers have discussed ways to tune DRAs and dielectric resonator oscillators. Tuning has been demonstrated by using varactor diodes [POPOVIC, N.: 'Novel method of DRA frequency tuning with varactor diode', Electronics Letters, 1990, 26, (15), pp 1162-1162] and [VIRDEE, B.S.: 'Effective technique for electronic tuning a dielectric resonator', Electronics Letters, 1997, 33, (4)]. A method has been found to tune a DRA by varying a gap between double dielectric resonators [HOWSON, D.P. AND SANI, B.M.: 'UHF double dielectric resonator filter with linearised tuning range', Electronics Letters, 1995, 31, (19), pp 1652-1653]. Similar arrangements are discussed in KAJFEZ, D. AND GUILLON, P. (Eds.) ['Dielectric resonators', Artech House, Inc, Norwood, MA, 1986].

One paper presents an adjustable frequency DRA [LI, Z., WU, C. AND LITVA, J.: 'adjustable frequency dielectric resonator antenna', Electronics Letters, 1996] in which conducting disks of various diameters are placed on top of the DRA to alter the frequency. Another paper [LEUNG ET. AL.: 'Offset dual-disk dielectric resonator antenna of very high permittivity', Electronics Letters, 1996, 32, (22)] describes how disks of dielectric material can be placed on top of a DRA – in this case not for tuning but to increase the bandwidth. KAJFEZ, D. AND GUILLON, P. (Eds.) ['Dielectric resonators', Artech House, Inc, Norwood, MA, 1986] discuss how metal disks may be used on top of a dielectric resonator and screwed down onto, or

up away from, the dielectric resonator so as to affect a frequency change.

Summary of the invention

According to the present invention, there is provided a dielectric resonator antenna including a dielectric resonator and a grounded substrate, the dielectric resonator having a first surface proximal to the grounded substrate and a second surface distal from the grounded substrate, a directional feed mechanism associated with the first surface for transferring energy to and from the dielectric resonator, and at least one directional conductive element located on or adjacent to the first and/or second surface, the dielectric resonator antenna being configured so as to allow a relative directional disposition of the feed mechanism and the at least one conductive element to be varied and thereby to vary a resonant frequency of the antenna.

Preferably, the antenna is configured so as to allow the relative directional disposition of the feed mechanism and the at least one conductive element to be to be varied in a cyclical manner.

Alternatively or in addition, the resonant frequency of the antenna may be changed by way of a translational movement of the dielectric resonator and/or the at least one conductive element relative to the feed mechanism, for example by way of sliding the dielectric resonator over the grounded substrate or by displacing the at least one conductive element on the dielectric resonator. In this case, the expression "relative directional disposition" encompasses, in the context of the present application, a translational movement of the dielectric resonator and/or the at least one conductive element relative to the feed mechanism, even when the directional conductive element and the directional feed mechanism remain substantially parallel, perpendicular or at some other relative angle.

For the avoidance of doubt, the expression "directional" is used here to denote a feed mechanism arrangement or conductive element geometry that is not circularly

symmetrical. In the context above, variance of the relative directional disposition of the feed mechanism and the conductive element in a cyclical manner means, for example, that the conductive element may be rotated relative to the feed mechanism, possibly about a longitudinal axis of the dielectric resonator passing through the first and second surfaces, such that a full rotation brings the feed mechanism and the conductive element from a given relative directional disposition to the same relative directional disposition, passing through different relative directional dispositions during the rotation. In particularly preferred embodiments, the cyclical variation is substantially sinusoidal when plotted along a time axis. More detailed description of this feature will be given hereinbelow.

The first surface of the dielectric resonator may contact the grounded substrate directly, or may be separated therefrom by a layer of dielectric material or an air gap. Where the dielectric resonator is separated from the grounded substrate, an operational bandwidth of the DRA is generally increased.

The dielectric resonator may be made out of a ceramic material or any other appropriate dielectric material with suitable relative permittivity.

In preferred embodiments, the first and second surfaces of the dielectric resonator are substantially parallel, and are preferably of the same shape and size. Advantageous dielectric resonator geometries include cylindrical (with the first and second surfaces being substantially circular, elliptical or ovate), and prismatic (with the first and second surfaces being squares, rectangles, parallelograms, regular or irregular polygons, semicircles, quarter circles, sectors and the like). Advantageously, an HE resonance mode is employed, although it is possible that other resonance modes may also be employed.

The at least one conductive element may be made of a suitable metal and may be generally rectangular, triangular, polygonal, elliptical or any other appropriate shape not displaying circular symmetry when rotated in a plane. In a particularly preferred

embodiment, the at least one conductive element comprises a generally rectangular, planar elongate strip that is placed on the first and/or second surface of the dielectric resonator. One or both end portions of the strip may be folded over edge regions of the first and/or second surface so as to contact a sidewall or sidewalls of the dielectric resonator. In a particularly preferred embodiment, the strip extends from an edge region of the surface to a centre point thereof (optionally extending along a sidewall of the dielectric resonator). For example, where the surface is substantially circular, the strip may extend along a radius of the circle from a centre point thereof. In embodiments where at least one conductive element is located on the first surface, the first surface may be separated from the grounded substrate by an air gap or other dielectric material so that the conductive element does not contact the grounded substrate. Alternatively, the first surface and the conductive element may be arranged so that the conductive element does touch the grounded substrate.

The feed mechanism is advantageously configured as a slot feed in the grounded substrate, comprising an oblong slot in the grounded substrate and a transmission line feeding the slot from a side of the grounded substrate remote from the first surface of the dielectric resonator. The transmission line is advantageously separated from the grounded substrate by a layer of dielectric material, such as a printed circuit board (PCB).

Alternative feed mechanisms include microstrip transmission lines and appropriately configured probe feeds.

It some embodiments, the feed mechanism has a directional aspect (e.g. a linear extension) that can be cyclically varied with respect to a directional aspect (e.g. a linear extension) of the at least one conductive element, preferably by way of relative rotation.

When the feed mechanism and the at least one conductive element are rotated relative to each other, for example by rotating the dielectric resonator about a

longitudinal axis passing through the first and second surfaces, the present applicant has found that a resonant frequency of the DRA varies cyclically as a function of the relative directional disposition of the feed mechanism and the at least one conductive element. This allows the DRA of the present invention to be tuned to different resonant frequencies within a predetermined range, which has important implications for mobile telecommunications and other applications. For example, the DRA can be tuned so as to resonate at 1.8GHz or at 1.9GHz by way of a simple rotational change of configuration, thereby providing compatibility with both European and US GSM standards.

Advantageously, the dielectric resonator may be provided with a ratcheted dielectric ring or the like allowing it to be rotated between two or more well-defined positions, each tuning the DRA to a different predetermined resonance frequency. The ratcheted ring may, for example, be made of a plastics material and mounted between the grounded substrate and the first surface of the dielectric resonator, thereby acting as a layer of dielectric material and providing bandwidth improvement. To provide for selection between 1.8GHz and 1.9GHz resonance frequencies, for example, the ratcheted ring may have only two stops defining two different relative rotational positions.

Brief description of the drawings

For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made by way of example to the accompanying drawings, in which:

FIGURE 1 shows a plan view of a first embodiment of the present invention with a single conductive element located on a second surface of a dielectric resonator;

FIGURE 2 shows a plan view of a second embodiment of the present invention with a pair of conductive elements located on a second surface of a dielectric resonator;

FIGURE 3 shows a side elevation of a third embodiment of the present invention with a single conductive element located on a first surface of a dielectric resonator;

FIGURE 4 is a graph showing how a resonant frequency of the embodiment of Figure 1 changes with rotation;

FIGURE 5 is a graph showing how a resonant frequency of the embodiment of Figure 2 changes with rotation;

FIGURE 6 is a graph showing how a resonant frequency of the embodiment of Figure 2 changes with rotation when an air gap is introduced between the first surface of the dielectric resonator and the grounded substrate;

FIGURE 7 shows a plan view of the DRA of Figure 1 centred on an origin of a Cartesian coordinate system;

FIGURE 8 shows the dielectric resonator of Figure 7 being moved along one axis of the coordinate system;

FIGURE 9 shows a variation of the resonant frequency with distance along the axis of Figure 8;

FIGURE 10 shows the dielectric resonator of Figure 7 being moved along another axis of the coordinate system;

FIGURE 11 shows a variation of the resonant frequency with distance along the axis of Figure 10;

FIGURE 12 shows a plan view of the DRA of Figure 1 in an alternative configuration centred on an origin of a Cartesian coordinate system;

FIGURE 13 shows the dielectric resonator of Figure 12 being moved along one axis of the coordinate system;

FIGURE 14 shows a variation of the resonant frequency with distance along the axis of Figure 13;

FIGURE 15 shows the dielectric resonator of Figure 12 being moved along another axis of the coordinate system;

FIGURE 16 shows a variation of the resonant frequency with distance along the axis of Figure 15; and

FIGURE 17 is a graph showing how a resonant frequency of a modified embodiment of Figure 1 changes with rotation.

Detailed description of preferred embodiments of the present invention

Figure 1 shows a first embodiment of a DRA of the present invention comprising a cylindrical ceramic dielectric resonator 1 of relative permittivity $E_r = 86$, disposed with a first circular surface (not shown) on a grounded substrate 2 and a second circular surface 3 distal from the grounded substrate 2. An oblong slot 4 is provided in the grounded substrate 2, and the grounded substrate 2 is itself mounted on a dielectric FR4 circuit board (not shown). A feed line 6 provided on an opposed side of the circuit board acts, together with the slot 4, as a feeding mechanism for transferring energy to and from the dielectric resonator 1. A conductive element comprising an oblong, planar copper strip 5 of width 1.70mm is located on the second surface 3 of the dielectric resonator 1. The copper strip 5 does not extend across the full diameter of the second surface 3, but merely over a radius thereof from an edge region to a central point. It can be seen that the feeding mechanism has a directional aspect defined by a longitudinal extent of the slot 4, and that the

conductive element has a directional aspect defined by a longitudinal extent of the copper strip 5. By rotating the dielectric resonator 1 about its longitudinal axis, the copper strip 5 and the slot 4 can be cyclically aligned and misaligned, i.e. their relative directional dispositions are cyclically varied upon rotation of the dielectric resonator 1.

By rotating the dielectric resonator 1 (and hence the copper strip 5) about its longitudinal axis while measuring a resonant frequency F_0 of the DRA, the plot shown in Figure 4 was obtained, with F_0 shown against the angle of rotation θ as shown in Figure 1. It was found that F_0 varied in a sinusoidal manner between about 2372MHz and 2295MHz, with F_0 having maxima at 0° and 180°, and minima at 90° and 270°.

The variation in F_0 with θ appeared to follow a response proportional to $(1+\cos 2\theta)/2$. The average radiation efficiency remained almost the same for each reading, showing that rotation of the dielectric resonator 1 does not appear to change the average efficiency level.

Figure 2 shows a second embodiment of a DRA of the present invention, similar in all respects to that of Figure 1, except that there is provided a second copper strip 5' disposed on the second surface 3 substantially orthogonal to the original copper strip 5.

By rotating the dielectric resonator 1 (and hence the copper strips 5, 5') about its longitudinal axis while measuring a resonant frequency F_0 of the DRA, the plot shown in Figure 5 was obtained, with F_0 shown against the angle of rotation θ as shown in Figure 2. It was found that F_0 varied in a sinusoidal manner between about 2415MHz and 2235MHz, with F_0 having maxima at 0°, 90°, 180° and 270°, and minima at 45°, 135°, 225° and 315°.

There are more F_0 peaks than with the embodiment of Figures 1 and 4, and the variation in F_0 with θ appeared to follow a response proportional to $(1+\cos 4\theta)/2$. Despite this change in frequency, the measured azimuth pattern remained consistent with that of an HE mode resonance throughout the experiment without much change in the location of the associated null in the azimuth radiation pattern. A further interesting observation was that, although the average F_0 for both the embodiment of Figures 1 and 4 and that of Figures 2 and 5 was almost the same, the embodiment of Figures 2 and 5 showed a wider range of F_0 variation than that of Figures 1 and 4.

By extension, it would appear that the provision of further copper strips 5 on the second surface 3 of the dielectric resonator 1 may result in general frequency variations of the form $(1+\cos 2n\theta)/2$, where n is the number of copper strips 5.

The experiments described above were repeated, but this time an air gap was introduced between the first surface of the dielectric resonator 1 and the grounded substrate 2. It is to be appreciated that air is a dielectric material, and that the air gap could instead be a layer of a plastics or other dielectric material with low relative permittivity E_r. It was found that, with the air gap, the bandwidth of the DRA (expressed as a percentage of F_0) increased by around 50%. F_0 was also found to increase as the distance between the grounded substrate 2 from the first surface was increased, from an average of 2301MHz to 2756MHz.

For small air gaps of less than 0.2mm there was no significant change in the average efficiency, but for air gaps of about 1.5mm the efficiency degraded by about 12dB to 15dB. This degradation is to be expected as less power will be coupled from the slot 4 into the dielectric resonator 1 as the height of the air gap increases.

Another trend observed was that with the increase in air gap, the variation in F_0 *increased* from 67.47MHz to 134.96MHz for a single copper strip 5 on the second surface 3, but *decreased* from 172.45MHz to 97.47MHz when two copper strips 5, 5'

were used, as shown in Figure 6. The trace 7 in Figure 6 is for the DRA with a single copper strip 5, and the trace 8 is for the DRA with a pair of copper strips 5, 5'.

Figure 3 shows a third embodiment of a DRA according to the present invention, comprising a dielectric ceramics resonator 1 identical to that of Figures 1 and 2, having a first surface 9 and a second surface 3. A copper strip 5 is this time located on the first surface 9 rather than the second surface 3, and is bent upwardly at the edges of the first surface 9 so as to contact the sidewalls of the dielectric resonator 1. The dielectric resonator 1 is located above the grounded substrate 2, which is in turn disposed on a dielectric circuit board 10. Because of the presence of the copper strip 5 on the first surface 9, an air gap 11 is introduced between the first surface 9 and the grounded substrate 2.

The results obtained for this DRA were broadly similar to those obtained for the embodiment of Figures 1 and 3. With no extra air gap 11 other than that introduced by the thickness of the copper strip 5, the percentage bandwidth was better than that for the experiments with no air gap 11 and the copper strip 5 on the second surface 3. As the air gap 11 was increased further, the bandwidth improved, but at the expense of efficiency.

Figure 7 shows a DRA arrangement similar to that of Figure 1, with a cylindrical ceramic dielectric resonator 1 of relative permittivity $E_r = 86$, disposed with a first circular surface (not shown) on a grounded substrate 2 and a second circular surface 3 distal from the grounded substrate 2. An oblong slot 4 is provided in the grounded substrate 2, and the grounded substrate 2 is itself mounted on a dielectric FR4 circuit board (not shown). A feed line 6 provided on an opposed side of the circuit board acts, together with the slot 4, as a feeding mechanism for transferring energy to and from the dielectric resonator 1. A conductive element comprising an oblong, planar copper strip 5 is located on the second surface 3 of the dielectric resonator 1, the strip 5 having a first end 13 located at a centre of the second surface 3, and a second end 14 located at a circumference of the second surface 3.

There is also shown a set of Cartesian coordinates centred on an origin 12, with an axis d defining a distance along the line of the slot 4, and an axis g defining a distance perpendicular thereto.

By moving the dielectric resonator 1 across the grounded substrate 2 along the g axis at $d=0$, as shown in Figure 8 (note that the conductive copper strip 5 remains parallel to the slot 4), the resonant frequency F_0 is changed as a function of the distance moved, as shown in Figure 9. The position $g=a$ on Figure 8, where a is the width of the slot 4, corresponds to a position where the copper strip 5 no longer "overlaps" the slot 4 when viewed perpendicularly from above. F_0 peaks at point $\pm b$ on Figure 9, where b is a distance along the g axis about ½ to 2/3 the distance between $g=0$ and $g=a$. As can be seen in Figure 9, F_0 decreases rapidly to zero just as the copper strip 5 no longer has any "overlap" with the slot 4 at positions $\pm a$.

Alternatively, by moving the dielectric resonator 1 across the grounded substrate 2 along the d axis at $g=0$, as shown in Figure 10 (note that the copper strip 5 moves in line with the slot 4), the results shown in Figure 11 are obtained. In Figure 10, the slot 4 is shown as having first 15 and second 16 ends, and the strip 5 has first 13 and second 14 ends as in Figures 7 and 8. F_0 peaks just short of point $+a$, which is where the first end 15 of the slot 4 is just being exposed from under the dielectric resonator 1, but then rapidly falls to zero upon further movement along the d axis to point $+a$. F_0 is also zero at point $-a$, which is where the second end 16 of the slot 4 is just being exposed from under the dielectric resonator 1. At $d=0$, F_0 is about half of its maximum value measured just short of point $+a$.

The reason that F_0 falls to zero once the slot 4 is exposed from under the dielectric resonator 1 is because power can then no longer be coupled from the slot 4 into the dielectric resonator 1, and resonance therefore no longer occurs.

Figure 12 shows a DRA having a similar configuration to that of Figures 7 and 10, with the exception that the copper strip 5 is disposed substantially orthogonal to the slot 4. All other features are labelled in the same manner as in Figures 7 and 10.

Figure 13 shows the dielectric resonator 1 of Figure 12 being moved along the *g* axis at *d*=0. F_0 is found to vary with the distance moved along the *g* axis, as shown in Figure 14, having a maximum value just short of $-a$, which is where corners of the ends 15, 16 of the slot 4 are just being uncovered by the dielectric resonator 1. At $+a$, which is again where corners of the ends 15, 16 of the slot 4 are just being uncovered by the dielectric resonator 1 (but in the opposite direction along the *g* axis), F_0 falls to zero, which is also the value at $-a$ and positions therebeyond.

Figure 15 shows the dielectric resonator 1 of Figure 12 being moved along the *d* axis at *g*=0. As shown in Figure 16, F_0 peaks at points $\pm b$ along the *d* axis, where *b* is a distance along the *d* axis about ½ to 2/3 the distance between *d*=0 and $d=\pm a$, where positions $\pm a$ correspond to positions where the ends 15, 16 of the slot 4 are just being exposed by the dielectric resonator 1. As can be seen in Figure 16, F_0 decreases rapidly to zero just as the slot 4 is exposed at positions $\pm a$.

Finally, Figure 17 shows a plot of F_0 against θ for a DRA similar to that of Figure 1, but having a copper strip 5 of width 2.55mm rather than 1.70mm. As can be seen, the greater width of the strip 5 results in a smaller sinusoidal variation of F_0.

CLAIMS:

1. A dielectric resonator antenna including a dielectric resonator and a grounded substrate, the dielectric resonator having a first surface proximal to the grounded substrate and a second surface distal from the grounded substrate, a directional feed mechanism associated with the first surface for transferring energy to and from the dielectric resonator, and at least one directional conductive element located on or adjacent to the first and/or second surface, the dielectric resonator antenna being configured so as to allow a relative directional disposition of the feed mechanism and the at least one conductive element to be varied and thereby to vary a resonant frequency of the antenna.

2. An antenna as claimed in claim 1, wherein the relative directional disposition of the feed mechanism and the at least one conductive element may be varied in a cyclical manner.

3. An antenna as claimed in claim 1 or 2, wherein the first and second surfaces of the dielectric resonator are substantially parallel.

4. An antenna as claimed in claim 1, 2 or 3, wherein the dielectric resonator has a substantially cylindrical configuration.

5. An antenna as claimed in claim 1, 2 or 3, wherein the dielectric resonator has a substantially prismatic configuration.

6. An antenna as claimed in any preceding claim, wherein the conductive element is substantially planar.

7. An antenna as claimed in claim 6, wherein the conductive element is substantially oblong.

8. An antenna as claimed in claim 7, wherein the conductive element extends from a centre of the first and/or second surface to an edge region thereof.

9. An antenna as claimed in claim 8, wherein the conductive element extends beyond an edge region of the first and/or second surface and along a sidewall of the dielectric resonator.

10. An antenna as claimed in any preceding claim, wherein the first surface of the dielectric resonator contacts the grounded substrate.

11. An antenna as claimed in claim 10, wherein the at least one conductive element is provided only on the second surface of the dielectric resonator.

12. An antenna as claimed in any one of claims 1 to 9, wherein an air gap is provided between the first surface of the dielectric resonator and the grounded substrate.

13. An antenna as claimed in claim 12, wherein the at least one conductive element is provided only on the first surface of the dielectric resonator.

14. An antenna as claimed in claim 12, wherein at least one conductive element is provided on the first surface of the dielectric resonator and at least one further conductive element is provided on the second surface of the dielectric resonator.

15. An antenna as claimed in any preceding claim, wherein the feed mechanism includes an elongate slot in the grounded substrate.

16. An antenna as claimed in any preceding claim, wherein the antenna is provided with means for varying the relative directional dispositions of the at least one conductive element and the feed mechanism in a step-wise manner.

17. An antenna as claimed in claim 16, wherein the dielectric resonator is mounted in a ratcheted ring allowing the dielectric resonator and the at least one conductive element to be rotated between discrete ratchet positions relative to the directional disposition of the feed mechanism, thereby enabling the antenna to be tuned to different predetermined resonant frequencies.

18. A dielectric resonator antenna substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Application No: GB 0206412.9
Claims searched: 1-17

Examiner: S M Colcombe
Date of search: 10 December 2002

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A		GB 2268626 A (SEC. STATE DEFENCE)
A		US 6198450 B1 (ADACHI)
A		JP 110308039 (CASIO)

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Field of Search:

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The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO